

## TECHNIQUES FOR RESOLVING NETWORK CONNECTIVITY

### BACKGROUND

[0001] A Local Area Network (LAN) can generally be defined as a broadcast domain. A  
5 broadcast domain includes a set of all devices operating in a portion of a network that will  
receive broadcast frames (frames directed to all devices in the set) originating from any device  
within the set. Certain types of network devices, including hubs, bridges, or switches, operating  
in the same physical LAN segment(s) of the network, can connect all end node devices within  
the segment(s). Consequently, end nodes can communicate with each other within the physical  
10 LAN segment(s) without the need for a router. Communication with devices on other LAN  
segments in the network requires the use of a router.

[0002] As networks expand, additional routers can be used to address bandwidth concerns,  
separate users into different broadcast (and collision) domains, and provide connectivity to other  
LANs in the network. Separating users into different broadcast domains can be useful, as  
15 broadcast requests can add a significant amount of traffic to the network that is "heard" by all  
nodes in the network. As this network grows, the broadcast traffic has the potential impact of  
flooding the network and making it essentially unusable.

[0003] Routers operate at the network level (Layer 3) of the Open System Interconnection  
(OSI) reference model. Routers use information included in a data packet, used to carry  
20 information, to determine destinations and route the information to the appropriate end node.  
The routing process can add latency that can delay the transmission of the information to the end  
node.

[0004] Bridges operate at the data link layer (Layer 2) of the OSI model, and typically add less  
latency than routers. Generally, a bridge can segment a LAN by filtering or forwarding an  
25 incoming frame based on a media access control (MAC) address of the frame. A bridged

network operates as a single broadcast domain, resulting in any broadcast requests being sent to all ports within the bridged network. Consequently, bridges can be utilized to solve bandwidth problems but cannot be used to create separate broadcast domains.

[0005] Switches also operate at the data link layer (Layer 2) of the OSI model, and also 5 typically add less latency than do routers. Generally, switches operate similar to bridges, but can be logically partitioned into separate broadcast domains called Virtual LANs, or VLANs. This logical partitioning can be used to limit the scope of broadcast requests to the individual VLANs themselves. VLANs can be viewed as a group of devices, perhaps on different physical LAN segments, that can communicate with each other as if they were all on the same physical LAN 10 segment.

[0006] Using switches to logically partition a LAN segment into VLANs (having separate broadcast domains) not only adds less latency than adding a router to divide the LAN segment, but often provides a more cost-effective solution as well. In addition, VLANs can be used to group end users based on traffic patterns, irrespective of physical location, e.g., to optimize 15 bandwidth utilization in the network or to address security concerns by limiting the scope of broadcast transmissions. Because each VLAN broadcast domain is considered a separate subnet, a single router is still required to exchange information between the VLANs. Typically, the router interface is a member of all of the VLANs between which it routes information.

[0007] When a switch is configured to logically partition a LAN segment into a VLAN, the 20 VLAN is assigned an identifier, commonly referred to as a VLAN identifier. The assigned VLAN identifiers are not guaranteed to be unique across all broadcast domains. Accordingly, when VLAN information is collected for resolving network connectivity, the information cannot be readily used to distinguish among VLANs having the same VLAN identifier, but operating on separate broadcast domains. Consequently, all devices included in VLANs having the same

VLAN identifier can be considered to be part of the same VLAN, even though all of the devices may not be logically partitioned into the same broadcast domain.

## SUMMARY

[0008] Accordingly, techniques are disclosed for resolving network connectivity. According to 5 an exemplary embodiment, a determination is made whether a first device is included in a portion of a network in which the first device can receive information directed to all devices included within the portion of the network. A first identifier associated with the portion of the network is obtained. A second identifier is assigned to the portion of the network unique to other portions of the network. The first identifier associated with the portion of the network is 10 modified to include the second identifier. The modified first identifier is associated with the first device and the portion of the network.

[0009] According to another exemplary embodiment, a system is described for resolving 15 network connectivity. The system includes memory and a processor. The processor includes logic configured to determine, using information stored in the memory, whether a first device is included in a portion of a network in which the first device can receive information directed to all devices included within the portion of the network. The processor also includes logic configured to obtain, from the memory, a first identifier associated with the portion of the network. Logic is included in the processor that is configured to assign a second identifier to the portion of the network unique to other portions of the network. The processor also includes logic 20 configured to modify the first identifier associated with the portion of the network to include the second identifier. Additional logic included in the processor is configured to associate the modified first identifier with the first device and the portion of the network.

#### BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The accompanying drawings provide visual representations which will be used to more fully describe the representative embodiments disclosed herein and can be used by those skilled in the art to better understand them and their inherent advantages. In these drawings, like 5 reference numerals identify corresponding elements, and:

[0011] FIG. 1 is a flowchart illustrating a method for resolving network connectivity according to an exemplary embodiment;

[0012] FIG. 2 illustrates a system for resolving network connectivity according to another exemplary embodiment; and

10 [0013] FIG. 3 illustrates a portion of a network topology map that can be generated using the techniques described for resolving network connectivity.

#### DETAILED DESCRIPTION

[0014] FIG. 1 is a flowchart illustrating a method for resolving network connectivity. In block 102, a determination is made whether a first device is included in a portion of a network in which 15 the first device can receive information directed to all devices included within the portion of the network. Generally, the portion of the network can be a broadcast domain and the information can be a broadcast message. According to an exemplary embodiment, the portion of the network can be a VLAN. Network topology discovery software, such as Hewlett Packard's (HP's) OpenView Network Node Manager (NNM) Extended Topology Version 1.5, can be used to 20 determine whether the first device is included in a portion of a network, such as a broadcast domain or VLAN.

[0015] Next, in block 104, a first identifier associated with the portion of the network is obtained. For example, according to an exemplary embodiment, the first device can be a network switch. The network switch can be configured to logically partition a LAN segment

into a VLAN representing the portion of the network. The network switch can include a Management Information Base (MIB) configured to store an identifier of the VLAN, which can be the first identifier. In such an arrangement, the first identifier (or VLAN identifier) associated with the portion of the network (or VLAN) can be obtained using a Simple Network

5 Management Protocol (SNMP) query to retrieve the VLAN identifier stored in the MIB.

[0016] According to yet another exemplary embodiment, the first device can be a port included in a network switch. In this arrangement, the network switch can be configured to logically partition a LAN segment connected to the port of the switch into a VLAN representing the portion of the network. The network switch can again include a MIB configured to store an

10 identifier of the VLAN, which can be the first identifier. The first identifier (or VLAN identifier) associated with the portion of the network (or VLAN) can again be obtained using an SNMP query to retrieve the VLAN identifier associated with switch port stored in the MIB.

[0017] Next, in block 106, a second identifier is assigned to the portion of the network that is unique to other portions of the network. For example, in an arrangement where the portion of 15 the network is a VLAN associated with a network switch and/or switch port, a second identifier, such as a domain identifier, can be assigned to the broadcast domain defined by the VLAN. The second identifier (or domain identifier) assigned to the VLAN is different than the domain identifiers assigned to other VLAN broadcast domains in the network arrangement. The second identifier (or domain identifier) is assigned to represent the portion of the network (or VLAN) in 20 addition to the first identifier (or VLAN identifier) already associated with the network portion.

The second identifier can be different than, or can be the same as the first identifier.

[0018] Next, in block 108, the first identifier associated with the portion of the network is modified to include the second identifier. For example, the second identifier can be appended to the first identifier to create a conjunctive identifier. The first identifier can be modified in any

way to include the second identifier (e.g., through string manipulation, mathematical operation, etc.). As the second identifier is unique to other portions of the network, the modified first identifier will uniquely identify the portion of the network among other such portions of the network.

5 [0019] Finally, in block 110, the modified first identifier is associated with the first device and the portion of the network. The association can be stored, e.g., in a table in memory, or can occur dynamically, e.g., through the use of software.

[0020] Associating the modified first identifier with the first device and the portion of the network can be useful in a number of ways. For example, according to an exemplary 10 embodiment, a first symbol, identifying the first device, can be presented connected to a second symbol, identifying the portion of the network, using the modified first identifier. Such a presentation can be used in conjunction with network management software, such as HP's NNM Extended Topology, to display a network topology map showing the association of the first device with the portion of the network.

15 [0021] For example, FIG. 3 shows a presentation having a first symbol 302 representing a network switch (e.g., "c55-sc0.cnd.hp.com") as the first device, and a second symbol 304 representing a VLAN (e.g., "VLAN\_3\_5") as the portion of the network. The modified first identifier "VLAN\_3\_5" shown can be used in presenting a connection 306 between the network switch "c55-sc0.cnd.hp.com" and the VLAN "VLAN\_3\_5". The connection can represent the 20 association between the switch and the VLAN.

[0022] The association between the first device and the portion of the network can also be presented in a tabular form as shown in Table 1. Proper VLAN connectivity for the three italicized switches ("cisco4.cnd.hp.com", "c55-sc0.cnd.hp.com", and "cisco2.cnd.hp.com") shown in FIG. 3 can be presented using a modified first identifier (VLAN\_3\_5) that includes the

VLAN identifier (VLAN ID 3) of the switches, and a unique broadcast domain identifier (Domain ID 5) associated with the switches. Port identifiers can be included in the table, as shown, to indicate the ports of a switch participating in a particular VLAN broadcast domain.

**Table 1 - Table showing correct VLAN connectivity using VLAN and domain identifiers**

VLAN Name (Modified First Identifier)	VLAN ID	Domain ID	Switch Names	Ports
VLAN_3_1	3	1	cat300-1.cnd.hp.com	7-14
VLAN_3_5	3	5	cisco4.cnd.hp.com c55-sc0.cnd.hp.com cisco2.cnd.hp.com	275 269 20-22
VLAN_3_6	3	6	cisco0.cnd.hp.com	53-76
VLAN_2_5	2	5	cisco4.cnd.hp.com cisco3.cnd.hp.com cisco2.cnd.hp.com c55-sc0.cnd.hp.com	274 7-8 17-19 267-268
VLAN_2_6	2	6	cisco1.cnd.hp.com	5-10
VLAN_10_5	10	5	cisco3.cnd.hp.com cisco4.cnd.hp.com c55-sc0.cnd.hp.com cisco0.cnd.hp.com	3-6 3-4 275-281 3-16
VLAN_100_5	100	5	cisco4.cnd.hp.com c55-sc0.cnd.hp.com cisco3.cnd.hp.com cisco0.cnd.hp.com	279-281 282-286 14-16 17-28

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[0023] According to another exemplary embodiment, a second device included in the portion of the network can be identified, and the modified first identifier can then be associated with the second device as well. For example, FIG. 3 shows a second network switch "cisco4.cnd.hp.com" connected to the VLAN "VLAN\_3\_5", representing an association between the second switch

10 and the VLAN. The association can also be presented in a tabular format as shown in Table 1.

[0024] Various aspects will now be described in connection with exemplary embodiments, including certain aspects described in terms of sequences of actions that can be performed by elements of a computer system. For example, it will be recognized that in each of the

embodiments, the various actions can be performed by specialized circuits or circuitry (e.g., discrete and/or integrated logic gates interconnected to perform a specialized function), by program instructions being executed by one or more processors, or by a combination of both.

Thus, the various aspects can be embodied in many different forms, and all such forms are

5 contemplated to be within the scope of what is described. For each of the various aspects, any such form of embodiment can be referred to herein as "logic configured to" perform, or "logic that" performs a described action.

**[0025]** A system for resolving network connectivity according to an exemplary embodiment is shown in FIG. 2. The system includes memory 202 and a processor 204. The processor includes 10 logic configured to determine, using information stored in the memory 202, whether a first device is included in a portion of a network in which the first device can receive information directed to all devices included within the portion of the network. As described in conjunction with the method shown in FIG. 1, the portion of the network can generally be a broadcast domain, and more specifically can be a broadcast domain defined by a VLAN. The information 15 can be a broadcast message directed to all devices within the VLAN. The processor 204 can execute network topology discovery software, such as HP's NNM Extended Topology, to determine whether the first device is included in a portion of a network.

**[0026]** The processor 204 also includes logic configured to obtain, from the memory 202, a first identifier associated with the portion of the network. For example, the first device can be a 20 network switch 208 configured to logically partition a LAN segment connected to the switch (or a switch port) into a VLAN 210 representing the portion of the network. The network switch can include a MIB 212 configured to store an identifier of the VLAN (e.g., VLAN\_3), which can be the first identifier. The first identifier (or VLAN\_3) associated with the portion of the network (or VLAN 210) can be obtained using an SNMP query to retrieve the VLAN identifier

associated with switch 208 or switch port stored in the MIB 212. Although shown separately in the figure, the MIB 212 can be a portion of the memory 202.

[0027] The processor 204 also includes logic configured to assign a second identifier to the portion of the network unique to other portions of the network. For example, in an arrangement 5 where the portion of the network is the VLAN 210 associated with the network switch 208 and/or a switch port, a second identifier, such as a domain identifier (e.g., Domain\_5), can be assigned to the broadcast domain defined by the VLAN 210. The second identifier (or domain identifier Domain\_5) assigned to the VLAN 210 is different than other domain identifiers (e.g., Domain\_1) assigned to other VLAN broadcast domains 214 in the network arrangement. The 10 second identifier (Domain\_5) is assigned to represent the portion of the network (VLAN 210) in addition to the first identifier (VLAN\_3) already associated with the network portion. The second identifier can be different than (e.g., "5" versus "3"), or can be the same as the first identifier.

[0028] The processor 204 also includes logic configured to modify the first identifier 15 associated with the portion of the network to include the second identifier. For example, the second identifier can be appended to the first identifier to create a conjunctive identifier, such as the identifier VLAN\_3\_5 associated with VLAN 210 in FIG. 2. The first identifier can be modified in any way to include the second identifier (e.g., through string manipulation, mathematical operation, etc.). As the second identifier is unique to other portions of the 20 network, the modified first identifier will uniquely identify the portion of the network among other such portions of the network, e.g., VLAN 214.

[0029] The processor 204 also includes logic configured to associate the modified first identifier with the first device and the portion of the network. The association can be stored, e.g., in a table in the memory 202, or can occur dynamically, e.g., through the use of software. For

example, a table, such as that shown in Table 1, can be used to associate a modified first identifier with the first device and the portion of the network. In the second row of Table 1, a modified first identifier (VLAN\_3\_5) is shown to be associated with a portion of the network (VLAN\_3 in Domain 5) and a first device ("c55-sc0.cnd.hp.com").

5 [0030] Alternatively, "stitcher" programs included in network management software can be modified to associate the modified first identifier with the first device and the portion of the network. These programs "stitch together" network connectivity information to generate a network topology map, such as the map shown in FIG. 3. The following exemplary pseudo-code describes the modifications/additions that can be made to existing stitcher programs to associate  
10 the modified first identifier with the first device and the portion of the network.

```
main() {
    // Note: If two switches connect to each other directly, or through other
    // switches indirectly, they are considered to be neighbors in a same
    // broadcast domain.
15    switchSet = CreateSetOfAllSwitches();
    while switchSet <> empty {
        switch = SelectOneFromSet(switchSet);
        domainId = GetUniqueDomainId();
        AssignDomainIdToSwitch(domainId, switch);
        RemoveSwitchFromSet(switch, switchSet);
        20    neighbors = FindAllNeighborsOfSwitchInSet(switch, switchSet);
        AssignDomainIdToSwitch(domainId, neighbors);
        RemoveSwitchFromSet(neighbors, switchSet);
    }
25    // Note: VLAN objects in topology database have vlanId identifier.
    // For each VLAN object in topology database {
        Modify OBJECT_VLAN_{vlanId} -> OBJECT_VLAN_{vlanId}_{domainId}
    }
30 }
```

[0031] According to an exemplary embodiment, the system can include a display 206 operatively coupled to logic included in the processor 204 that is configured to present on the display 206 a first symbol identifying the first device, connected to a second symbol identifying  
35 the portion of the network using the modified first identifier. The display 206 can be a network management console, or the display 206 and processor 204 can be embodied in a network management station used to monitor and manage the network.

[0032] For example, FIG. 3 shows a portion of a network topology map that can be presented on the display 206, having a first symbol 302 representing a network switch (e.g., "c55-sc0.cnd.hp.com") as the first device, and a second symbol 304 representing a VLAN (e.g., "VLAN\_3\_5") as the portion of the network. The modified first identifier "VLAN\_3\_5" shown 5 can be used in presenting a connection 306 between the network switch "c55-sc0.cnd.hp.com" and the VLAN "VLAN\_3\_5". The connection can represent the association between the switch and the VLAN.

[0033] The processor 204 can also include logic configured to identify, using information stored in the memory 202, a second device included in the portion of the network. Logic 10 configured to associate the modified first identifier with the second device can also be included in the processor 204. The information stored in the memory 202 used in determining whether the first and second devices are included in a portion of a network, such as a VLAN, can include a first table having an entry associating an identifier of the network switch with the identifier of the VLAN. For example, Table 2 includes a text entry "mainName" providing a base name of a 15 switch, and text and integer entries "vlanStr" and "vlanId", respectively, for identifying the VLAN associated with the switch. Neighboring switch information, such as the "intName" entry, can also be included in the table.

**Table 2 - Information describing switch and VLAN associations**

No.	Column	Format	Remark
1	mainName	TEXT (NOT NULL)	Base name of a switch
2	intName	TEXT (NOT NULL)	Name of local neighbor
3	vlanStr	TEXT (NOT NULL)	OBJECT_VLAN_{vlanId}
4	vlanId	INTEGER	VLAN ID

[0034] The memory 202 can also include a second table having an entry associating an identifier of the network switch with the second identifier. For example, Table 3 includes a text entry "Name" providing a base name of a switch, and a text entry "Domain" identifying the VLAN broadcast domain associated with the switch.

5 **Table 3 - Information describing switch and domain associations**

No	Column	Format	Remark
1	Name	TEXT (NOT NULL)	Base name of a switch
2	Domain	TEXT (NOT NULL)	Name or ID of a domain

[0035] According to an exemplary embodiment, the first device can be coupled to other portions of the network by a network router. For example, in FIG 2, a router 216 is coupled to both VLANs 210, 214 to allow devices included in the VLANs 210, 214 to exchange information across the two VLAN broadcast domains. Recall that because each VLAN broadcast domain is considered a separate subnet, at least one router is still required to exchange information between the VLANs. Typically, the router interface is a member of all of the VLANs between which it routes information.

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[0036] The instructions of a computer program as illustrated in FIG. 1 for resolving network connectivity can be embodied in any computer readable medium for use by or in connection with an instruction execution system, apparatus, or device, such as a computer based system, processor containing system, or other system that can fetch the instructions from the instruction execution system, apparatus, or device and execute the instructions.

[0037] As used herein, a "computer readable medium" can be any means that can contain, store, communicate, propagate, or transport the program for use by or in connection with the instruction execution system, apparatus, or device. The computer readable medium can be, for

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example but not limited to, an electronic, magnetic, optical, electromagnetic, infrared, or semiconductor system, apparatus, device, or propagation medium. More specific examples (a non exhaustive list) of the computer readable medium can include the following: an electrical connection having one or more wires, a portable computer diskette, a random access memory 5 (RAM), a read only memory (ROM), an erasable programmable read only memory (EPROM or Flash memory), an optical fiber, and a portable compact disc read only memory (CDROM).

[0038] It will be appreciated by those of ordinary skill in the art that the concepts and techniques described herein can be embodied in various specific forms without departing from the essential characteristics thereof. The presently disclosed embodiments are considered in all 10 respects to be illustrative and not restrictive. The scope of the invention is indicated by the appended claims, rather than the foregoing description, and all changes that come within the meaning and range of equivalence thereof are intended to be embraced.